WESLEY COLLEGE
By daring & by doing

PHYSICS
YEAR 12
STAGE 3
Semester 1
2015

Wesley College

Name: SOLUTIONS

Teacher: ______________________

TIME ALLOWED FOR THIS PAPER
Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
- This Question/Answer Booklet; Formula and Constants sheet

To be provided by the candidate:
- Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.
- Special items: Calculators satisfying the conditions set by the Curriculum Council for this subject.

IMPORTANT NOTE TO CANDIDATES
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short answer	12	12	50	54	30
Section Two: Extended answer	7	7	90	90	50
Section Three: Comprehension and data analysis	2	2	40	36	20
			Total	180	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2013.* Sitting this examination implies that you agree to abide by these rules.

2. Write answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

4. You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Refer to the question(s) where you are continuing your work.

Section One: Short response **30% (54 Marks)**

This section has **11** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 50 minutes.

1. A 350 g model aeroplane is moving in a horizontal circle of radius 4.5 m and takes 6.0 seconds to complete a full circle,

(a) Label, on the diagram, the direction of the centripetal acceleration. (1)

(b) Calculate the velocity of the aeroplane (2)

$r = 4.5\,m$

$T = 6.0\,s$

$v = \frac{2\pi r}{T} = \frac{2 \times \pi \times 4.5}{6}$

$= \underline{4.71\,ms^{-1}}$

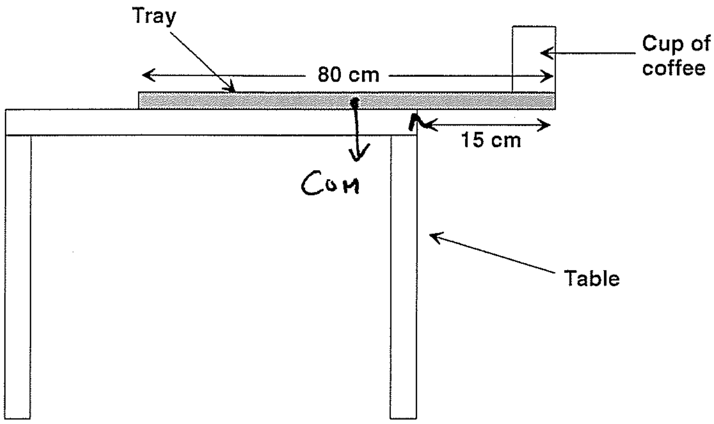
(c) Calculate the magnitude of the centripetal force (2)

$F_c = \frac{mv^2}{r}$

$= \frac{0.35 \times (4.71)^2}{4.5}$

$F_c = \underline{1.73\,N}$

2. A 0.4kg cup of coffee rests on the edge of a uniform tray lying on a table as shown in the diagram. Calculate the mass of the tray. (4)



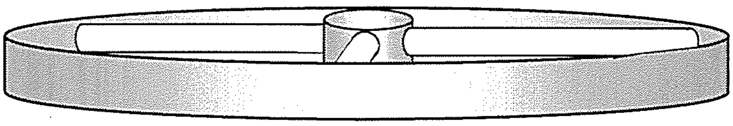
$$\Sigma cm = \Sigma acm$$

$$0.4 \times \cancel{9.8} \times 0.15 = 0.25 \times M \times \cancel{9.8}$$

$$M = \frac{0.4 \times 0.15}{0.25}$$

$$M = \underline{0.24 kg}$$

3. A space station rotates in space so as to simulate gravity in the region of its outer ring which has a diameter of 80 m.



At what rate (**revolutions per minute**) must the space station rotate to give a value for artificial gravity in the outer ring of 8.9 ms^{-2} (slightly less than that on Earth)? (5)

$$\frac{\cancel{m}v^2}{r} = \cancel{m}g \qquad v = \frac{2\pi r}{T}$$

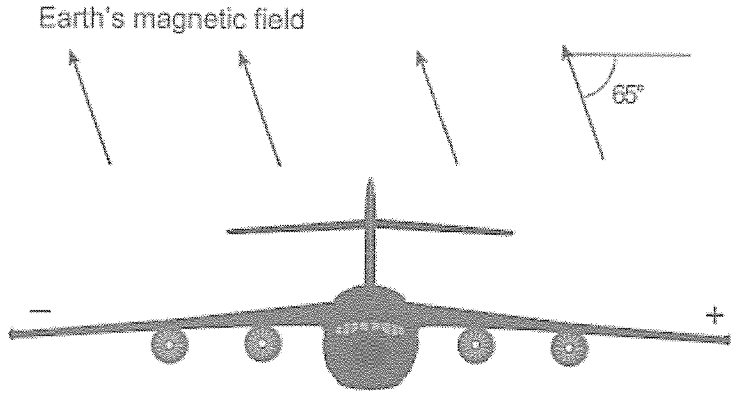
$$\frac{\frac{4\pi^2 r^2}{T^2}}{r} = g \qquad g = \frac{4\pi^2 r}{T^2} = \frac{4 \times \pi^2 \times 40}{T^2} = 8.9$$

$$T = \sqrt{\frac{4 \times \pi^2 \times 40}{8.9}}$$

$$T = 13.322s \text{ for 1 rev}$$

$$\frac{60}{13.322} = \underline{4.5 \text{ rev per min}}$$

4. An aeroplane is flying across Australia. The Earth's magnetic field, which acts at 65° to the horizontal and has a strength of 2.70×10^{-5} T, induces an emf between the wingtips of the aeroplane as shown below. (4 marks)



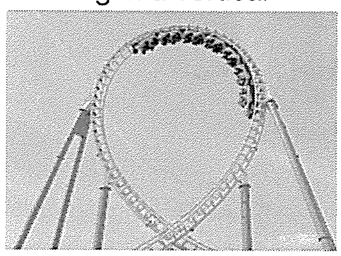
The aeroplane has a wingspan (distance from wingtip to wingtip) of 59.5 m and has a speed of 270 ms^{-1}. Calculate the emf induced. (4 marks)

vertical component $= 2.7 \times 10^{-5} \times \cos 25° = 2.45 \times 10^{-5}$ T (1) (1)

emf $= lvB = 59.5 \times 270 \times 2.45 \times 10^{-5}$ (1)

$= 0.394$ V (1)

5. A 76 kg passenger is upside down in a roller coaster that is travelling in a vertical loop of radius 43 m.



a) Calculate the minimum speed necessary for the passenger to not fall out of his seat? You should assume that he is not wearing a seatbelt. (2)

$\frac{mv^2}{r} = mg$

$v^2 = 43 \times 9.8$

$v = 20.5 ms^{-1}$

b) How would your answer have differed if the passenger only weighed 38 kg? Explain. (2)

No difference. Calculations above is independent of the passenger's mass.

6. Figures A and B below show two different configurations of a magnetic compass and a bar magnet lying together on a flat table.

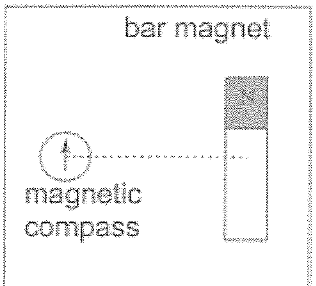


Figure A

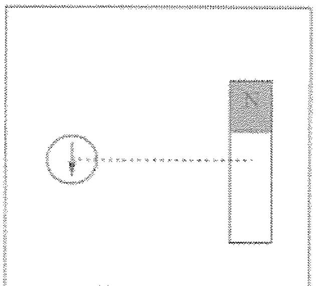


Figure B

a) Ignoring any effects due to the Earth's magnetic field, which of the two figures (A or B) correctly shows the direction of the compass needle. (1 mark)

B

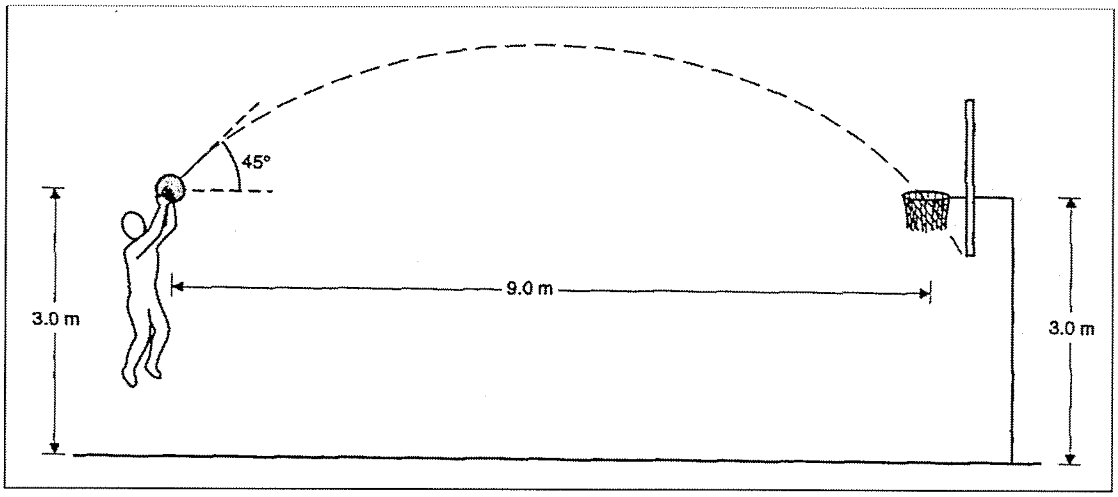
b) Explain carefully the reasons for your choice. (3 marks)

compass needle is a magnet with the arrow head a north pole (1)

it will align with the field of the bar magnet so that it points towards S, aligning N - S (2)

a good answer draws in the field, diagram (correct) is worth 1.

7. Shooting for a basket, a basketballer releases the ball at 45° above the horizontal when the centre of the ball is 3.0 m above the ground. It passes cleanly through the basket which is 3.0 m above the ground, and 9.0 m from the basketballer's hand. The acceleration due to gravity can be taken as $10ms^{-2}$. Air resistance can be neglected. The situation is shown in the diagram below.



The ball takes 1.34 s from leaving the player's hand to passing through the ring.

(a) Calculate the magnitude of the velocity of the ball as it leaves the player's hand. (2)

$$v_H = \frac{s}{t} = \frac{9}{1.34} = 6.7 ms^{-1}$$

$$\frac{6.7}{v} = \cos 45°$$

$$v = 9.47 ms^{-1}$$

(b) What was the highest point **above the ground**, reached by the centre of the ball? Show your working. (3)

$$v_V = 9.47 \sin 45 = 6.7 ms^{-1}$$

$$v^2 = u^2 + 2as$$

$$0^2 = (6.7)^2 - 2 \times 10 \times 5$$

$$s = 2.25 m$$

Distance above ground $= 2.25 + 3$

$= 5.25 m$

8. The following table shows data on three planets that orbit the Sun

Planet	**Average distance from the Sun (R) in metres**	**Period of orbit (T) in seconds**
Mercury	5.79×10^{10}	7.60×10^{6}
Venus	1.08×10^{11}	1.94×10^{7}
Earth	1.50×10^{11}	3.16×10^{7}

(a) Use **one** line of data to calculate the constant R^3/T^2 (1)

$$\frac{(5.79 \times 10^{10})^3}{(7.6 \times 10^6)^2} = 3.36 \times 10^{18}$$

(b) Use the constant to calculate the mass of the Sun. (4)

$$\frac{R^3}{T^3} = \frac{gM}{4\pi^2}$$

$$M = \frac{R^3}{T^2}\frac{4\pi^2}{g} = \frac{3.36 \times 10^{8} \times 4 \times \pi^2}{6.67 \times 10^{-11}} = 1.98 \times 10^{30}\ kg$$

9. A transformer is ideal in terms of voltage but only 92% efficient due to current losses. The primary coil has 560 turns and the secondary coil 392 turns. The voltage across the primary coil is 240 V. The secondary coil has 560 mA in it. Calculate the power into the primary coil and out of the secondary coil.

(4)

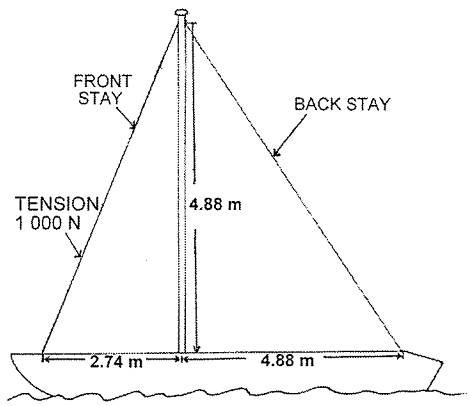
$$V_{sec} = \frac{392 \times 240}{560} = 168V \quad (1)$$

$$P_{sec} = 560 \times 10^{-3} \times 168 = 94.1\ W \quad (1)$$

$$P_{sec} = P_{pri} \times 0.92$$

$$P_{pri} = \frac{94.1}{0.92} = 102\ w \quad (2)$$

10. The figure below shows a sail boat. The mast is a uniform pole of 175.0 kg and is 4.88 m long. It is supported by the deck and held in position by front and back stays as shown. The tension in the front stay is 1 000.0 N.



Calculate the tension in the back stay. (4)

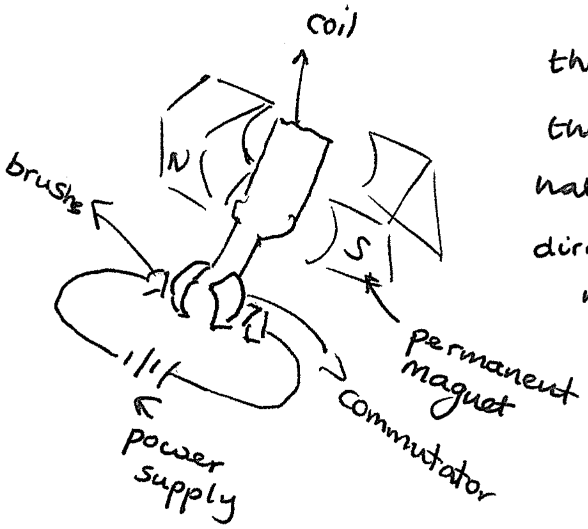
$\tan\theta = \dfrac{2 \cdot 74}{4 \cdot 88} = 29 \cdot 3°$

perpendicular distance of base of mast to front stay $= \dfrac{\sin 29 \cdot 3}{4 \cdot 88} = 2 \cdot 388m$ $\perp$ dist base to back stay $= \dfrac{\sin 45}{4 \cdot 88} = 3 \cdot 45m$

taking moments about base $T \times 3 \cdot 45 = 1000 \times 2 \cdot 388$

$T = 692N$

11. Draw a diagram of a D.C. motor. What does the spilt-ring commutator do? (4)



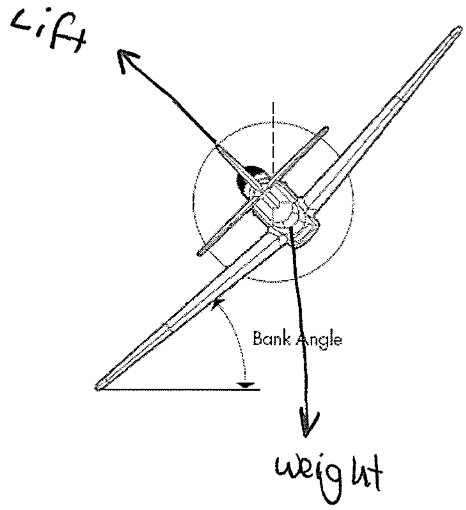
the commutator reverses the current at every half-turn because the direction of the current must be switched so that the coil can rotate.

12.

The diagram at right shows a cross-sectional view of an airplane as it banks while making a turn.

(a) On the diagram show the forces acting on the airplane as it banks to make the turn (ignore thrust and drag). (2)

(b) If the airplane banks at an angle of 26° while moving in a turning circle of radius 2.3 km, calculate its speed. (3)



$$\tan 26° = \frac{v^2}{rg}$$

$$v^2 = \tan 26 \times 2300 \times 9.8$$

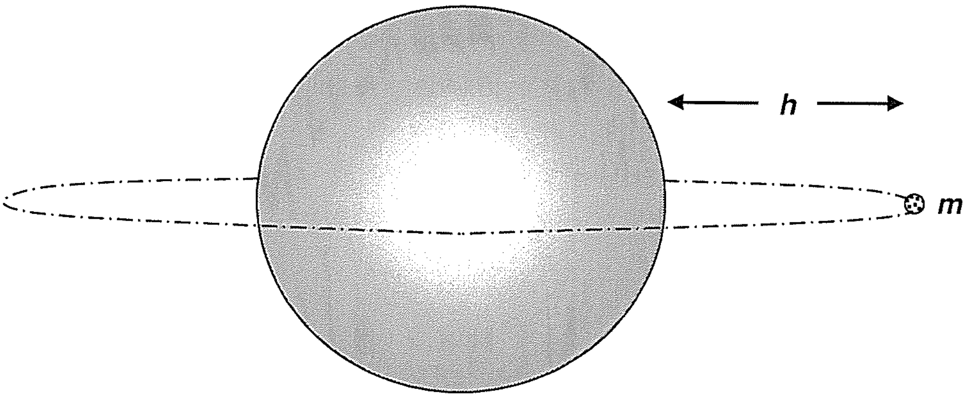
$$v = 105\ ms^{-1}$$

Section Two: Problem-solving **50% (90 Marks)**

This section has **eight (8)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 12. **(10 marks)**

A satellite of mass ***m*** follows a circular orbit around the Earth, at constant speed and at an altitude ***h*** above the Earth's surface as shown below.



(a) Calulate the orbital period of the satellite (1)

24 hours

(b) Calculate the height ***h*** of the satellite above the surface of the Earth. ~~(6)~~ (8)

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$$

$$R^3 = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times(24\times3600)^2}{4\times\pi^2}$$

$$R^3 = 7.54\times10^{22}$$

$$R = 4.22\times10^{7}\text{ m}$$

Height above Earth $= 4.22\times10^{7} - 6.37\times10^{6}\text{ m}$

$=$ ~~[illegible]~~

$= 3.58\times10^{7}\text{ m}$

(c) If the mass of the satellite is doubled, how will this affect its orbital radius? Give a reason for your answer. (2)

As $\frac{\cancel{m}v^2}{r} = \frac{G\cancel{m}M}{r^2}$ m's cancel

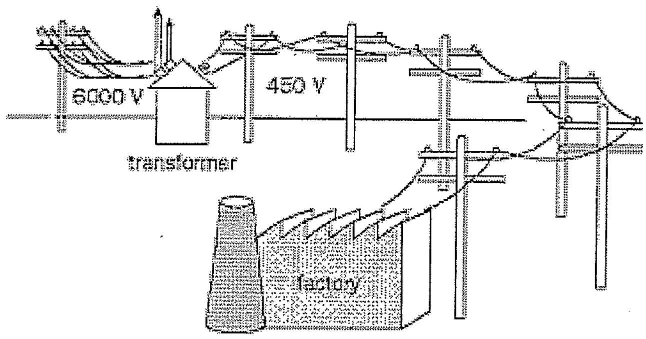
So no effect

(d) Name one use or application of geostationary satellites. (1)

Communication.

Question 13. **(10 marks)**

The diagram below shows electricity being supplied to a small factory. The main transmission lines supply power at 12 kV. A transformer reduces this to 600 V, after which two wires, each of length 1.0 km with a resistance of 1mΩ per metre, connect the transformer to the factory.



a). The primary coil of the transformer has 500 turns. Calculate the number of turns in the secondary coil. (1)

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \qquad N_s = \frac{V_s N_p}{V_p} = \frac{600 \times 500}{12 \times 10^3} = 25$$

In the questions below, 24 kW of electric power is being drawn from the output terminals of the transformer.

b). Calculate the current flowing in the factory supply wires. (2)

$$P = IV = \frac{\overset{(1)}{24} \times 10^3}{600} = \overset{(1)}{40A}$$

c). Calculate the power loss in the factory supply wires. (3)

$$P = I^2 R \qquad R = \underbrace{1 \times 10^{-3}}_{\Omega/m} \times \underbrace{1000}_{length} \times \underbrace{2}_{nu\ of\ wires} = 2\,\Omega\,(1)$$

$$P = 40^2 \overset{(1)}{} \times 2 = 3200\ \omega\,(1)$$

d). Calculate the voltage delivered to the factory. (2)

$$24 \times 10^3 - 3200 = 20,800\,(1)$$

$$\frac{20\ 800}{40} = 520V\ (1)$$

e). Why is it necessary to transmit alternating current at such high voltages? (2)

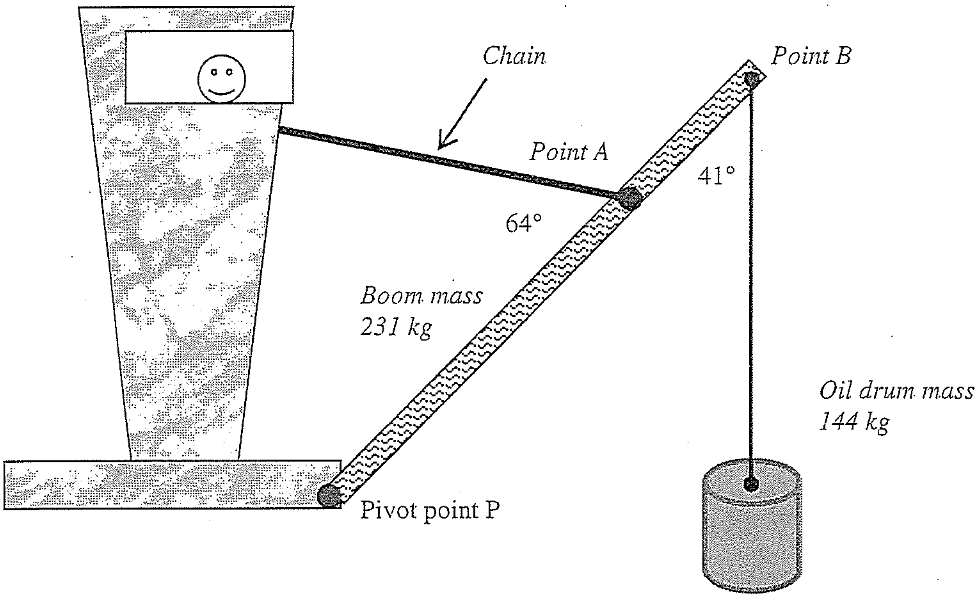
To reduce power losses (1)

If V↑ I↓ then P_{loss} is reduced (1)

Question 14 **(11 marks)**

A crane at Fremantle port is unloading an oil drum from a ship.

- The boom of the crane has a mass of 231 kg and is pivoted at point P.
- The oil drum of mass 144 kg is suspended from point B. Its rope makes an angle of 41° with the boom.
- A chain attached at point A is holding the boom in position. The distance from P to A is 3.80 m.
- The chain makes an angle of 64° with the boom.
- The boom has a length of 4.50 m from P to B with uniform mass distribution.



a. Demonstrate by calculation that the tension in the chain = 2.20 x 10^3 N. (6)

Σ ACM = Σ CM about pivot P

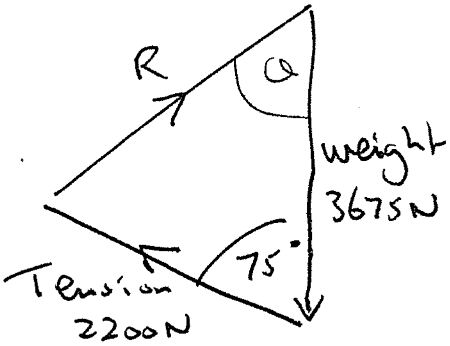
$3.8 \times F_T \times \sin 64 = (4.50 \times 144 \times 9.8 \sin 41) + (2.25 \times 231 \times 9.8 \sin 41)$

425.12 340.98

$F_T = \frac{7507.9}{3.8 \sin 64}$

$F_T = \underline{2198.23 \text{N}}$

b. Calculate the magnitude of the **reaction force** acting on the boom from the pivot. (4)



$$R^2 = W^2 + T^2 - 2WT\cos 75$$

$$R^2 = (3675)^2 + (2200)^2 - 2 \times 3675 \times 2200 \times \cos 75$$

$$\underline{R = 3763\text{N}}$$

c. Calculate the direction of the **reaction force** acting on the boom from the pivot. (3)

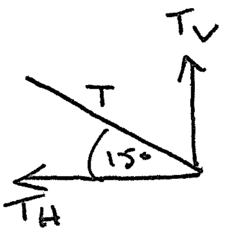
$$\frac{T}{\sin\theta} = \frac{R}{\sin 75}$$

$$\sin\theta = \frac{2200 \times \sin 75}{3763}$$

$$\sin\theta = 0.5677$$

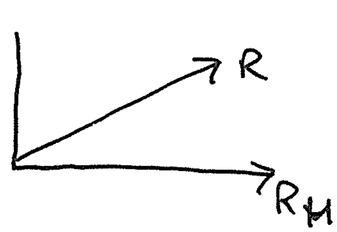
$$= 34.4° \text{ from the vertical.}$$

OR



Forces up = Forces down

Forces left = Force right



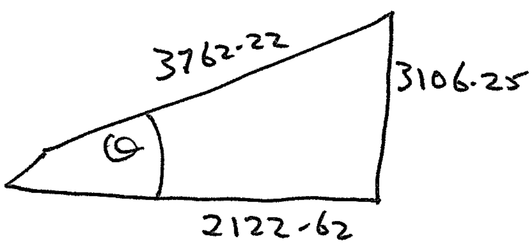
$$T_H = 2197.5\cos 15°$$
$$= 2122.62\text{N}$$

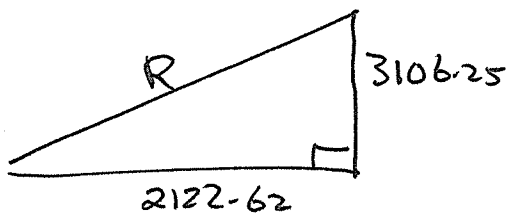
$$T_V = 2197.5\sin 15°$$
$$= 568.75\text{N}$$

FORCES DOWN $= 231 \times 9.8 + 144 \times 9.8$
$= 3675\text{N}$

$$R_V = 3675 - 568.75$$
$$= 3106.25\text{N}$$

$$R_H = 2122.62\text{ N}$$





$$R = \sqrt{3106.25^2 + 2122.62^2}$$

$$R = 3762.22\text{N}$$

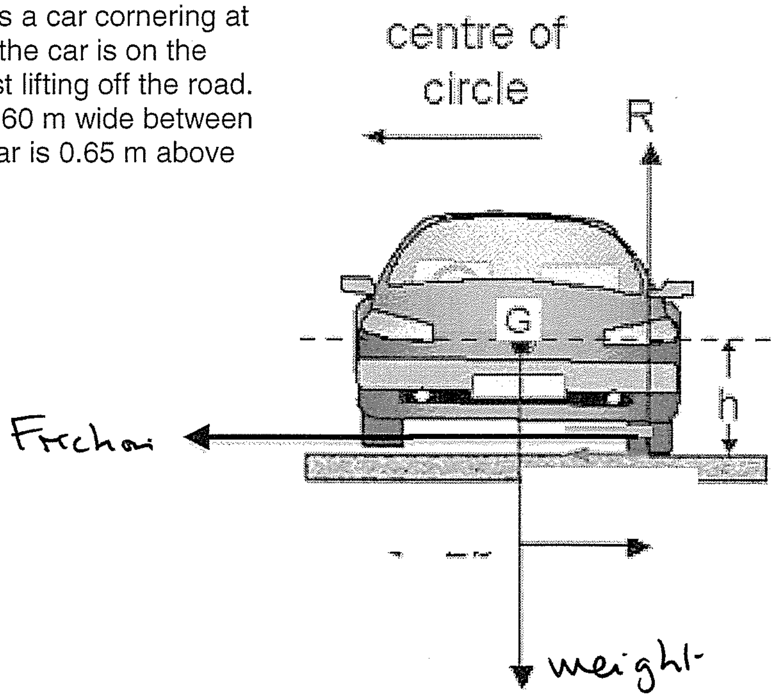
$$\tan\theta = \frac{3106.25}{2122.62}$$

$= 55.7°$ to horizontal

or $34.3°$ to vertical.

Question 15 **(12 marks)**

The cross section diagram at right shows a car cornering at high speed, such that all the "weight" of the car is on the outside tyres and the inside tyres are just lifting off the road. The car has a mass of 1850 kg and is 1.60 m wide between the tyres. The centre of mass G of the car is 0.65 m above the road.



(a) On the diagram, the normal reaction force R of the road on the outside tyres is shown. **Label** the other two important forces that act on the car as it moves around the corner in a circular path. (2)

(b) What is the size of the normal reaction force R of the road on the outside tyres? (treat the force R as a single force even though it acts on front and back tyres) (1)

$R = mg$

$= 1850 \times 9.8$

$= \underline{18100 N}$

(c) Calculate the torque produced by the normal reaction force R about the centre of mass of the car. (2)

$T = Fr$

$= 18100 \times 0.8 m$

$= \underline{14500 Nm}$ around CoM

(d) The car will roll over if the clockwise torque due to friction is larger than the anticlockwise torque due to the reaction force of the road. Calculate the maximum value of friction before the car rolls over when cornering. (3)

$\Sigma cm = \Sigma acm$

$F_f \times 0.65 m = 14500$

$F_f = \frac{14500}{0.65}$

$= \underline{22300 N}$

(e) Calculate the maximum speed of the car given it is moving around a curve with a radius of curvature of 25 m? (2)

$$F_f = F_c = \frac{mv^2}{r}$$

$$22300 = \frac{1850 \times v^2}{25}$$

$$v^2 = 302$$

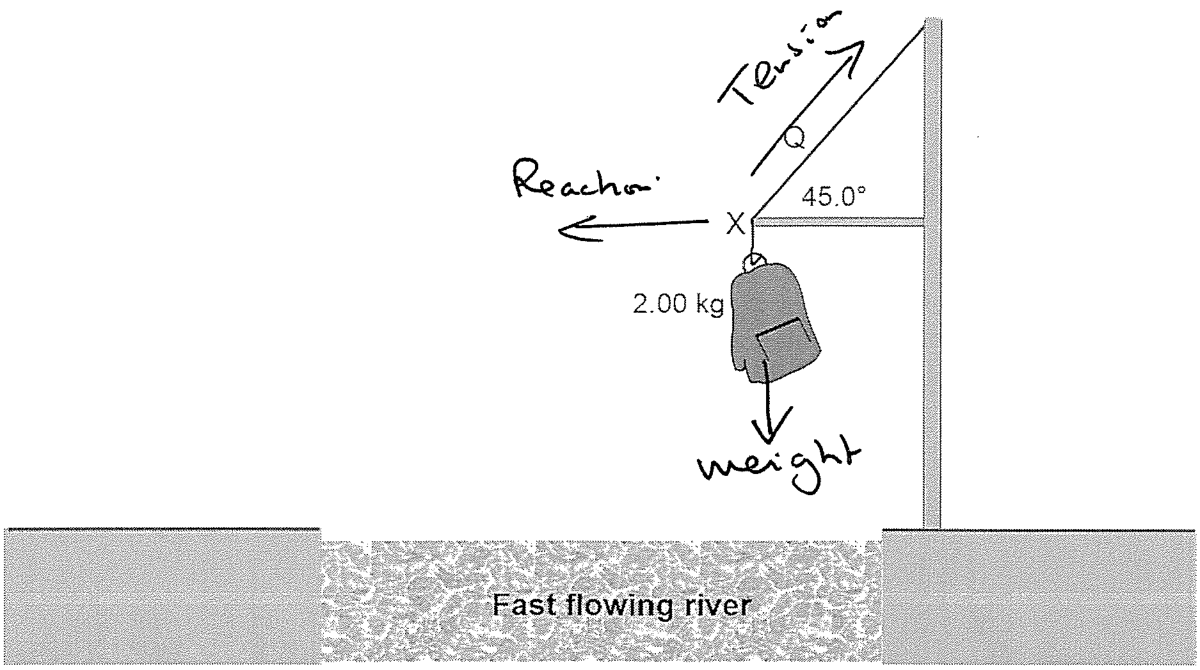
$$v = \underline{17.4 \text{ ms}^{-1}}$$

(f) On a wet day the road cannot provide as much friction to the tyres when the car is cornering. If the driver attempts to take the corner at the speed calculated above, what is the likely outcome? (2)

On a wet day friction is less
Tyres will skid out as the
car tries to corner.

Question 16 **(12 marks)**

A survival course requires trainees to retrieve a ration pack of mass 2.00 kg suspended from a rope above a fast flowing river, as shown in the diagram below.



(a) Determine the net force acting on the suspended pack. (1)

Zero

(b) On the diagram, draw arrows to represent the forces acting at point X. Ignore any frictional forces that might act at X. Label the forces (3)

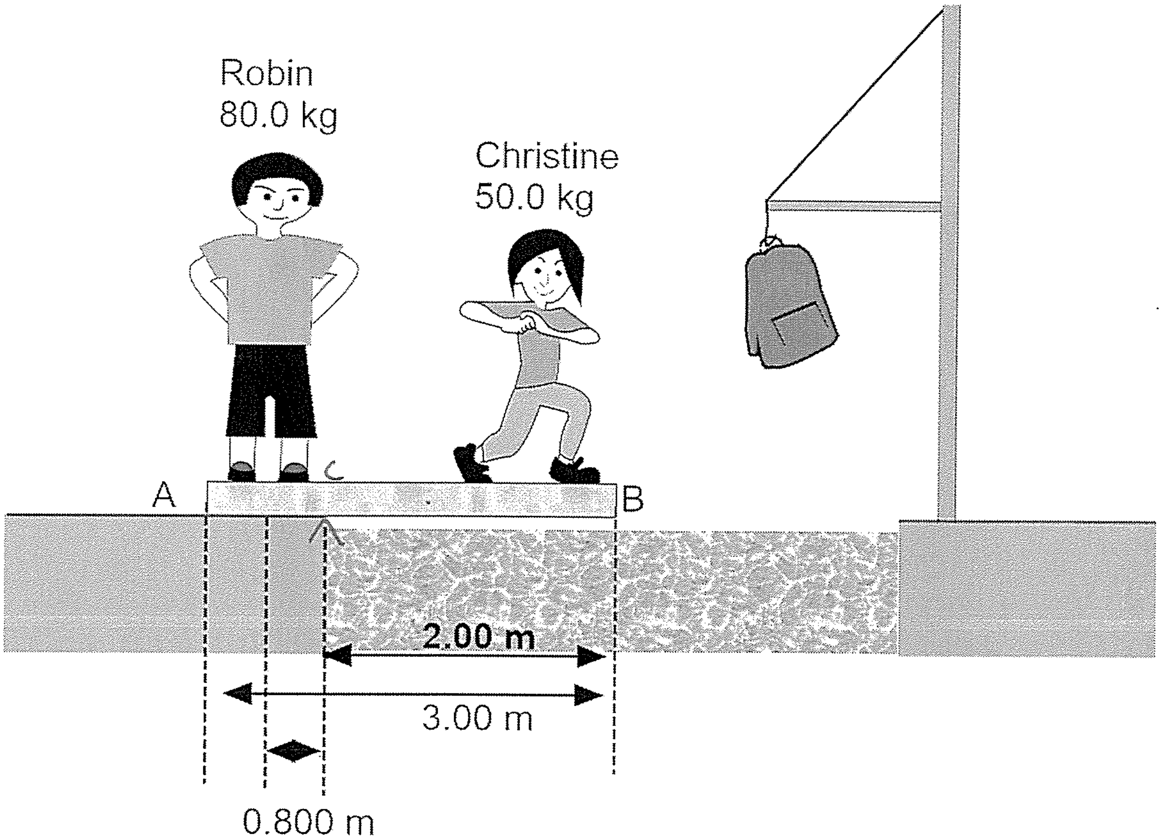
(c) Calculate the tension in the rope at the point marked Q. (3)

$T \sin 45 = mg$

$T = \dfrac{2 \times 9.8}{0.7071}$

$T = \underline{27.7 N}$

Robin, a trainee whose mass is 80.0 kg, is unable to reach the ration pack. Robin suggests to a friend, Christine, that they could use a 3.00 m long uniform plank of mass 12.0 kg as shown below.



Robin stands so that his centre of mass is 0.200 m from end A of the plank. With Robin holding down one end, the plank extends over the river bank by 2.00 m. Christine, of mass 50.0 kg, walks out along the plank toward end B.

d) Calculate how far Christine can safely walk along the plank before it tips. (5)

Take moments about C

$80 \times 9.8 \times 0.8 = 50 \times 9.8 \times y + 12 \times 9.8 \times 0.5$

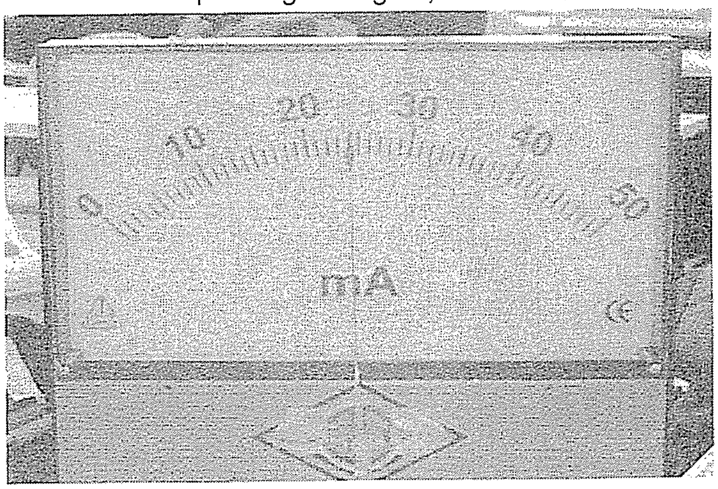
$6272.. = 58.8 + 490y$

$y = 1.16\text{m}$ (distance of Christine from C)

Question 17 **(16 marks)**

An analogue ammeter is a device that is used to determine the magnitude of electrical current. The unknown current is passed through a coil of wire in a magnetic field. The turning effect of the current-carrying coil is balanced by a spring and a corresponding value is read from the meter.

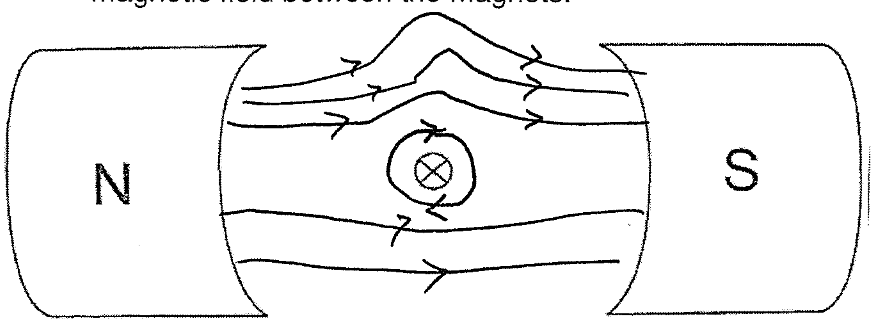
a) Use the photograph below of an ammeter's scale to determine the magnitude of the current passing through it, as well as the uncertainty in the measurement. (2)



Current: 24 mA

Uncertainty: ± 0.5mA

b) A simplified diagram representing one current-carrying wire of the ammeter's coil between two magnets is shown below. Draw enough field lines to show the resultant magnetic field between the magnets. (3)



c) Calculate the current in the wire in the simplified diagram, given that that the magnetic field strength is 5.20×10^{-2} T, the length of the wire in the field is 2.0×10^{-2} m and there is a force acting on the wire of 1.3×10^{-4} N. (2)

$F = BIL$

$I = \frac{F}{BL} = \frac{1.3\times10^{-4}}{5.2\times10^{-2} \times 2\times10^{-2}} = 0.13\,A$

d) The actual ammeter shown has 450 turns of wire that form a square coil with sides of 3.2×10^{-2} m. Determine the restoring torque of the spring, given that the magnetic field strength is 5.2×10^{-2} T and there is a current in the coil of 40mA. (4)

$F = NBIL$

$\tau = Fd$ where $d = \frac{1}{2}w$ but there is a torque on each ~~either~~ side so $\tau = 2Fd$

$\tau = NBILw$

$= 450 \times \cancel{3}\ 5.2\times10^{-2} \times 40\times10^{-3} \times 3.2\times10^{-2} \times 3.2\times10^{-2}$

$= 9.58\times10^{-4}$ Nm

e) When the ammeter is disconnected, the spring rotates the coil so that the marker needle returns to zero. This causes a change in flux of 5.32×10^{-5} Wb to occur in the coil inducing an emf of 0.08 V. Determine the time taken for the coil to rotate. You must include a unit in your answer. (3)

$EMF = \frac{N\Delta\phi}{\Delta t}$

$\Delta t = \frac{N\Delta\phi}{emf} = \frac{450\times5.32\times10^{-5}}{0.08} = 0.3\,s$

(1) (1) (1)

Question 18 **(17 marks)**

A generator used to provide electricity for an outdoor party consists of a coil of 300 turns. The coil is 15 cm long and 10 cm wide. It is connected to a portable motor that turns the coil at a rate of 4 000 revolutions per minute. The magnetic field in the generator is 0.2 T.

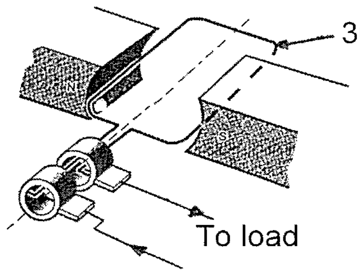


Fig 1

(a) Calculate the average emf produced by the generator. (5 marks)

4000 rev/minute time for 1 rev = 0·015 s (2)
average ~~emf~~ generated over 1/4 rev = 0·015 s / 4 = 0·00375 s

$$\text{emf} = \frac{300 \times 0{\cdot}2 \times 0{\cdot}15 \times 0{\cdot}10}{0{\cdot}00375} = 240\text{ V} \ (1)$$

(2)

(b) If the generator had slip rings (see Fig 1) would the current produced by the generator be AC or DC? Explain your answer. (2 marks)

AC (1)

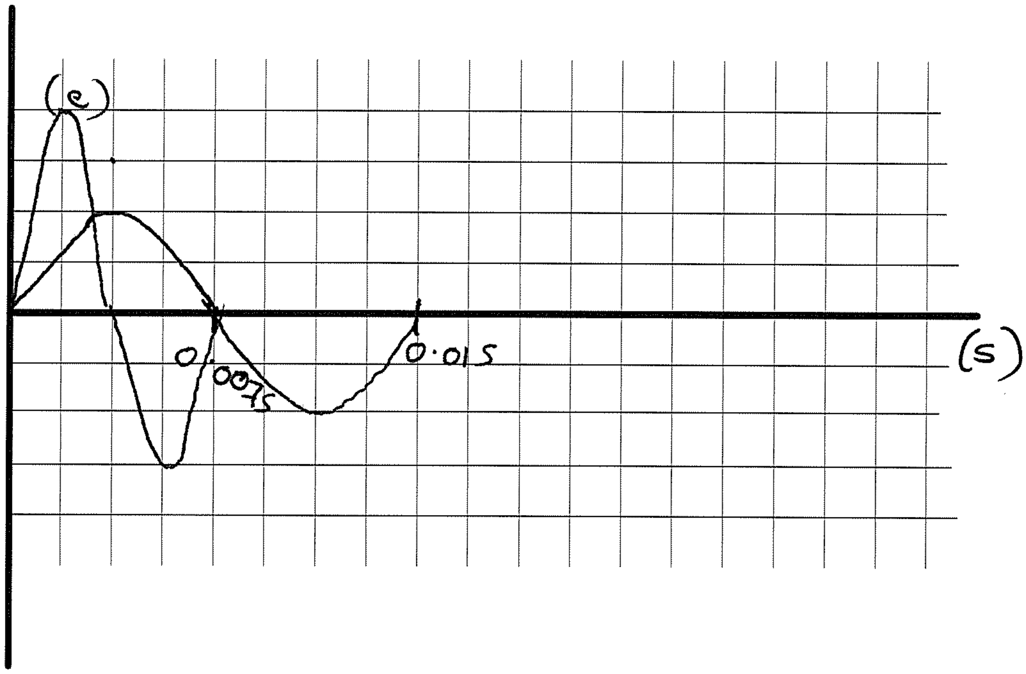
flux is changing in magnitude and direction every rotation (1)

(c) List two ways in which the generator could be modified to produce a greater emf. (2 marks)

- increase frequency (or speed)
- increase magnetic field
- increase number of turns

Any 2

(d) On the axis below draw a graph of the emf produced by the generator in one rotation. Be sure to label the axis and provide a scale for the x-axis including units. (3 marks)



(e) The frequency of the generator is doubled. Draw another line on your graph to show how the emf generated would change.
Label this line 'e' (2 marks)

½ the time (1)
×2 the peak (1)

(f) Although the rate of rotation is quoted at 4 000 rpm, will the emf produced by the generator be a constant voltage? Explain your answer. (2 marks)

No (1)

emf fluctuates between a minimum and a maximum as the coil links with the flux (1)

or no, it is A.C. (1)

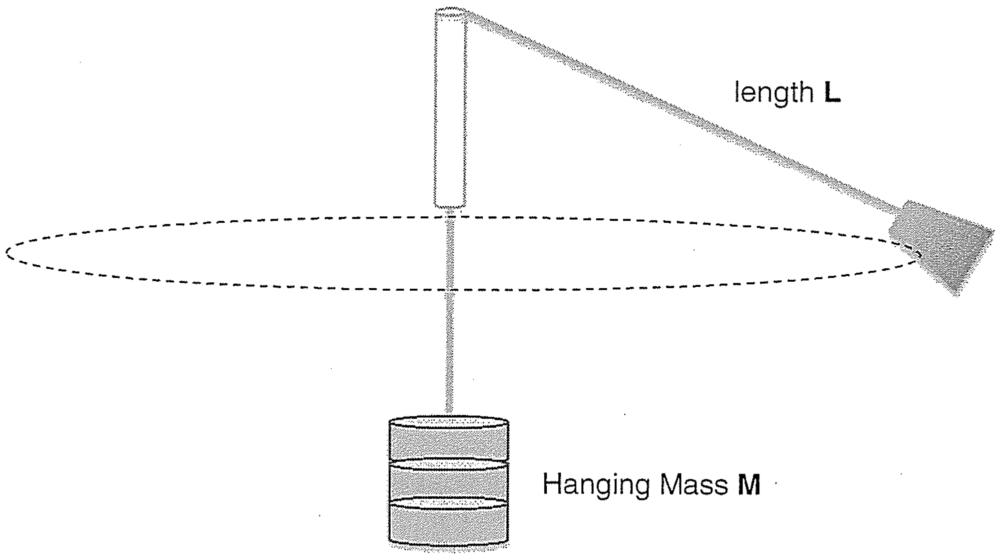
SECTION THREE: Comprehension and data analysis **36 marks (20%)**
This section contains **2** questions. You must answer both questions. Write your answers in the spaces provided. Suggested working time for this section is **36 minutes.**

Question 19

CONICAL PENDULUM

(20 marks)

A conical pendulum was set up as shown in the diagram below. Nylon fishing line was passed through a piece of glass tubing, with a mass **M** hanging below the glass tubing to provide tension in the line and a rubber stopper of mass **m** used as a bob revolving in a horizontal circle. A number of trials were conducted to investigate the relationship between the size of the hanging mass **M** and the period **T** of the conical pendulum (the time for one revolution of the bob). The length **L** of the line between the bob and the top of the glass tube was set at 500 mm.



The following raw data was obtained for a range of hanging masses.

Hanging Mass M (grams)	Time for 10 cycles (seconds)	M (kg)	T (s)	$1/T^2$
100	9.02	0.100	0.902	1.23
150	7.41	0.150	0.741	1.82
200	6.33	0.200	0.633	2.50
250	5.66	0.250	0.566	3.12
300	5.23	0.300	0.523	3.66
350	4.74	0.350	0.474	4.45
400	4.51	0.400	0.451	4.92

The relationship between mass **M** and period **T** was expected in theory to be

$$\mathbf{M} = (4\pi^2\mathbf{mL}) / (g\mathbf{T}^2)$$ where g is the acceleration due to gravity

(a) Complete the table for M (kg), T (s) and $1/T^2$ (3)

(b) Plot a graph of M against $1/T^2$ on the graph paper provided on the next page (an extra copy of graph paper is on the last page of this exam booklet if needed) (6)

(c) Calculate the gradient of the graph, include the unit. Show the measurements you have used on the graph (5)

$$\text{Gradient} = \frac{0.24\ \text{kg}}{3.0\ \text{s}^{-2}} \checkmark$$

$$= \underline{0.080\ \text{kg s}^{-2}} \checkmark$$

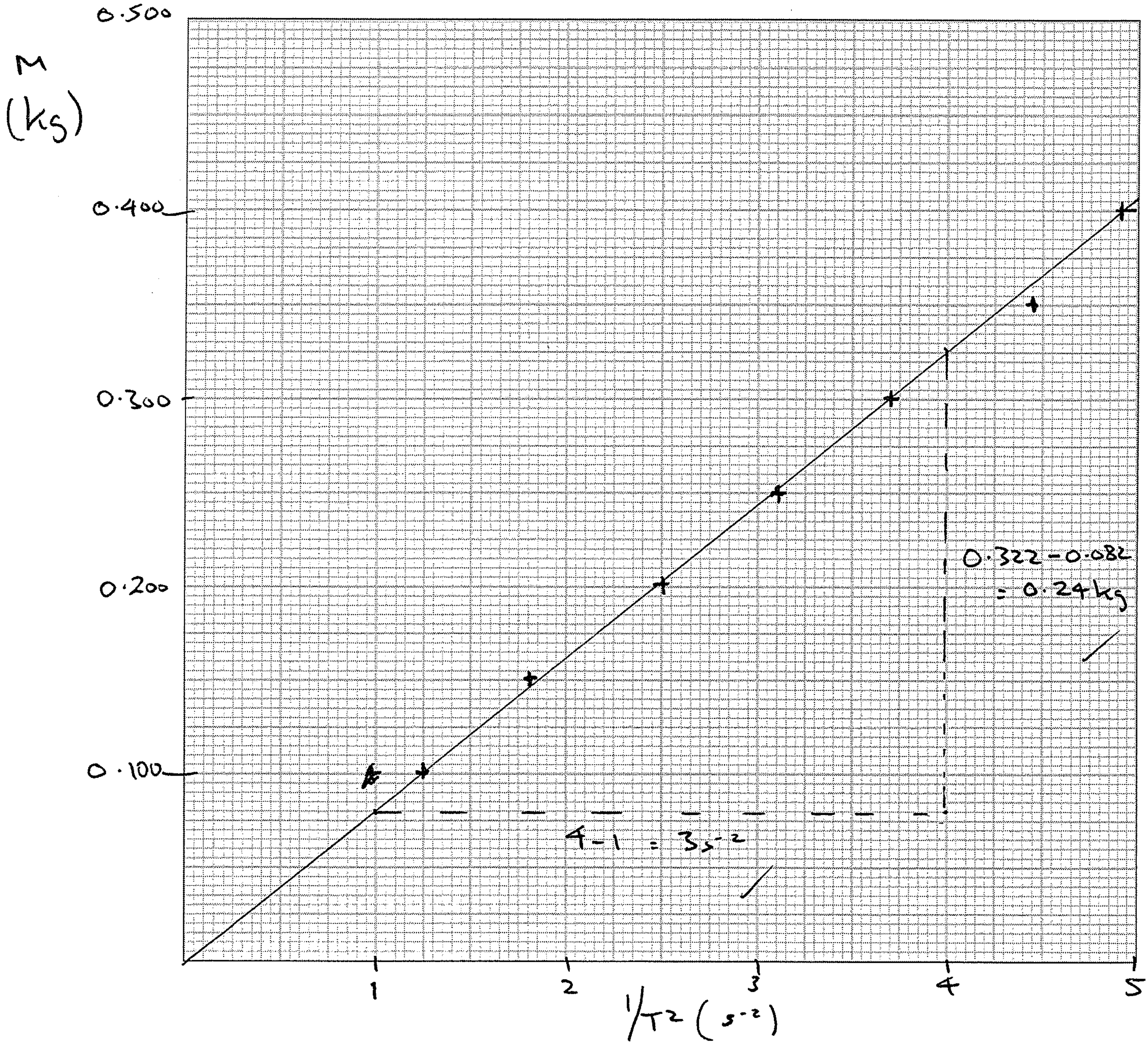
(e) Use your value of the gradient to determine the mass, m, of the bob used. (3)

$$\text{Gradient} = 4\pi^2 mL / g$$

$$m = \frac{g \times \text{gradient}}{4\pi^2 \times 0.500}$$

$$= \frac{9.8 \times 0.080}{4\pi^2 \times 0.500}$$

$$\text{mass} = \underline{0.040\ \text{kg}}$$



(f) Explain why it was decided to time 10 revolutions of the pendulum in each trial in order to find the period of the pendulum. (2)

10 revolutions instead of just one will reduce measurement error from timing with regard to reaction time of the person using a stopwatch

(g) For which trial would the percentage error in the period of revolution be smallest? (1)

First trial with m = 0.100kg and T = 0.902s

% error smallest for trial with the largest value of T.

Question 20 **(20 marks)**

Bicycle Tachometer

A common method for monitoring the speed of a bicycle is to attach a permanent magnet to the spokes of the wheel and mount a sensing coil on the frame, so on each revolution of the wheel the magnet passes close by without touching.

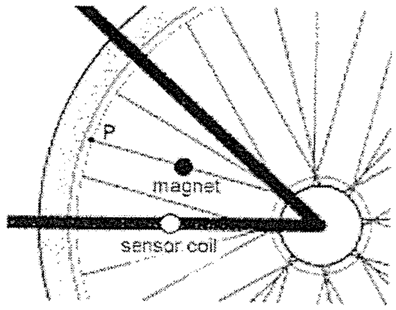


Figure 1: magnet and sensing coil mounted on bicycle.

A cylindrical magnet is used where one circular face is a north magnetic pole and the other south. The sensor is a circular coil of N turns with the same diameter as the magnet.

Figure 2 below shows the view from a point P fixed on the wheel looking toward the magnet as the wheel rotates. The sensing coil will appear to follow a path as shown in Figure 2. The field lines due to the magnet have been shown.

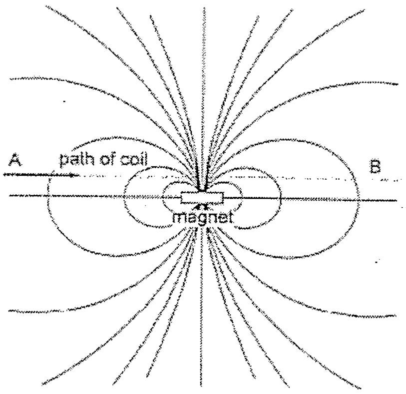


Figure 2: side on view of magnet showing field lies and sensor path (A to B).

As the sensing coil passes by the cylindrical magnet from A to B (figure 2), the magnetic flux through the coil induces a voltage across the coil as shown in Figure 3.

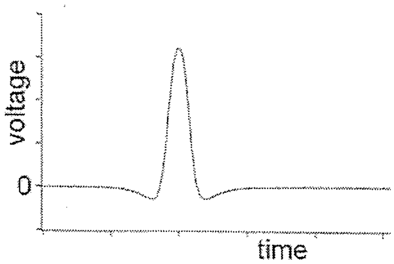


Figure 3: typical sensing coil output

To estimate the size of the voltage pulse we can approximate the change of magnetic flux through the coil as that due to an average magnetic field of strength B_0 acting over a time Δt such that:

$$emf = -\frac{\Delta\phi}{\Delta t} = -\frac{NB_0\pi D^2}{4\Delta t}$$

Where D is the diameter of the magnet (and coil) and N the number of turns in the coil.

If the wheel has an axle to ground radius of R and the magnet and coil are at a distance R_m, from the axle, then during one complete revolution of the wheel the magnet and coil will be aligned for approximately Δt, where

$$\Delta t = \frac{D}{2\pi R_m}T$$

Where T is the time it takes the wheel to do a single revolution.

For a bicycle travelling at a constant speed v the time for one revolution is given by:

$$T = \frac{2\pi R}{v}$$

a) If the bicycle is pushed backward, how would this affect the coil output? You may sketch the coil output to help your description. ~~(3)~~ (2)

The output will not be affected
It would still be inducing a
voltage but as the direction
of the magnet has changed the
voltage peak would still have
the same maximum value but
it would be in the opposite way to that shown.

b) If the magnet was reversed so that **North** became **South**, how would this affect the coil output when the bicycle was moving forward? You may sketch the coil output to help your description. ~~(3)~~ (2)

Output will be reversed in sign
but have the same shape.

c) Using the equations given in the text show that $emf \approx \frac{\pi}{4} ND \left(\frac{R_m}{R}\right) B_0 v$. You must show all the steps in your working. (3)

$$emf = \frac{-NB_0 \pi D^2}{4\Delta t} \qquad \Delta t = \frac{D}{2\pi R_m} \qquad T = \frac{2\pi r}{v} ✓$$

$$\Delta t = \frac{D}{\cancel{2\pi} R_m} \times \frac{\cancel{2\pi} R}{v} = \frac{DR}{R_m v} ✓$$

Sub into emf $\frac{N}{4} B_0 \pi \times \frac{R_m v}{\cancel{D} R} \times D^{\cancel{2}} = \frac{\pi}{4} ND\left(\frac{R_m}{R}\right)B_0 v$ ✓

Consider a particular example for a bicycle with the following values:

wheel radius:	$R = 0.27$ m
magnet position:	$R_m = 0.20$ m
field strength:	$B_0 = 0.10$ T
magnet diameter:	$D = 0.010$ m

d) Calculate the number of voltage pulses that would occur if the bicycle travelled 1.0 km. (2)

$$\text{No. of pulses} = \frac{\text{distance}}{2\pi R} = \frac{1000}{2\pi \times 0.27} ✓$$

$$= \underline{589} ✓$$

e) Calculate the number of turns the coil should have in order to generate 1.0 V at a speed of 10 m s^{-1}. (3)

$$e.m.f = \frac{\pi}{4} ND\left(\frac{R_m}{R}\right) B_0 v$$

$$N = \frac{4 \times e.m.f \times R}{\pi D R_m B_0 v} = \frac{4 \times 1 \times 0.27}{\pi \times 0.01 \times 0.2 \times 0.1 \times 10}$$

$$= \underline{172} ✓$$

f) Why is there a slight dip before and after the main peak in the coil response? (4)

Coil approaching magnet from A in fig2 passes through a part of the field that is in the opposite direction to when directly in front of the magnet; therefore voltage direction is opposite
The field is weaker further from the magnet so only a small dip registers.

End of Section Three - End of Questions

Extra graph paper for Question 19